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~~Report~~ USAMC-ITC-02-08-76-418

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CONCEPT DEVELOPMENT AND PRELIMINARY HAZARD ANALYSIS OF AUTOMATED HANDLING SYSTEMS FOR HIGH EXPLOSIVES - SCAMP MODULE B.

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November 1975

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Final Report.

12 79p.

APPROVED FOR PUBLIC RELEASE:
DISTRIBUTION UNLIMITED

Prepared for

SAFETY GRADUATE ENGINEERING PROGRAM
AND TEXAS A&M UNIVERSITY GRADUATE CENTER
USAMC Intern Training Center - USALMC
Texarkana, Texas 75501

408 058

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FOREWORD

The research discussed in this report was accomplished as part of the Safety Engineering Graduate Program conducted jointly by the USAMC Intern Training Center and Texas A&M University. As such, the ideas, concepts and results herein presented are those of the author and do not necessarily reflect approval or acceptance by the Department of the Army.

This report has been reviewed and is approved for release. For further information on this project contact Dr. George D.C. Chiang, Safety Engineering, Intern Training Center, Red River Army Depot, Texas 75501.

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: USAMC-ITC-02-08-76-418

2. GOVT ACCESSION NO.:

3. RECIPIENT'S CATALOG NUMBER:

4. TITLE (and Subtitle): CONCEPT DEVELOPMENT AND PRELIMINARY HAZARD ANALYSIS OF AUTOMATED HANDLING SYSTEMS FOR HIGH EXPLOSIVES - SCAMP MODULE B

5. TYPE OF REPORT & PERIOD COVERED: FINAL

6. PERFORMING ORG. REPORT NUMBER:

7. AUTHOR(s): Kenneth R. Heflin

8. CONTRACT OR GRANT NUMBER(s):

9. PERFORMING ORGANIZATION NAME AND ADDRESS:
Dept of Safety Engineering
USAMC Intern Training Center
Red River Army Depot, Texarkana, Texas

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS:

11. CONTROLLING OFFICE NAME AND ADDRESS:
Dept of Safety Engineering and
Texas A&M University Graduate Center
USAMC Intern Training Center - USALMC

12. REPORT DATE: November 1975

13. NUMBER OF PAGES: 69

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office): Same as above

15. SECURITY CLASS. (of this report):

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE:

16. DISTRIBUTION STATEMENT (of this Report):
Approved for Public Release: Distribution Unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report):

18. SUPPLEMENTARY NOTES:
Research performed by Kenneth R. Heflin under the supervision of Dr. J.M. CoVan, Assistant Professor, Industrial Engineering, Texas A&M University.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number):
SCAMP MODULE B, High Explosives Handling, Automated Material Handling, Preliminary Hazard Analysis.

20. ABSTRACT (Continue on reverse side if necessary and identify by block number):

This report encompasses the determination and preliminary analysis of material handling systems concepts for automatically measuring, dispensing, and transferring High Explosives and High Explosive Incendiaries. A set of system criteria is developed recognizing and conforming to physical, environmental, and safety constraints. These system requirements are used as a guide for determining two general system concepts for accomplishing the handling tasks.

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 SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

Cont

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This report encompasses the determination and preliminary analysis of material handling systems concepts for automatically measuring, dispensing, and transferring High Explosives and High Explosive Incendiaries. A set of system criteria is developed recognizing and conforming to physical, environmental, and safety constraints. These system requirements are used as a guide for determining two general system concepts for accomplishing the handling tasks listed earlier. A Preliminary Hazards Analysis is performed on the proposed system concept to identify, evaluate, and eliminate or control hazards of the system.

ACKNOWLEDGEMENTS

I would like to express my gratitude to Dr. J.M. CoVan, Chairman of my committee, for his guidance in the development of this report. I wish to thank Mr. C.J. Clarkson, SCAMP System Analyst for Texas A&M University, for his help in providing information for this report. My thanks also goes to Mr. Charles Litz for help in providing system requirements. Finally, I would like to thank my wife, [redacted], for her assistance in the typing and editing of this report.

During the course of this work, the author was employed by the U.S. Army as a career intern in the AMC Safety Engineering Graduate Program. He is grateful to the Army for the opportunity to participate in the program.

The ideas, concepts, and results herein presented are those of the author and do not necessarily reflect approval or acceptance by the Department of the Army.

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CHAPTER I

INTRODUCTION

The production of small caliber ammunition used by the Armed Forces involves complicated processes containing many steps and procedures. Inherent hazards abound in these processes. Explosive materials are moved, stored, processed, packaged, and shipped. Each operation requires a power source to convert the form of the projectile or case to a more desired form. Any source of power provides a potential source of a hazard and must be considered when designing safety into a system.

For years archaic methods had been used to produce small caliber ammunition. Virtually all operations were performed manually. These methods were tedious, expensive, and time consuming. Yet few changes were made primarily because the existing techniques had satisfied the requirements placed upon them. Surprisingly enough, safety was not considered a problem area largely due to the fact that safety performance was strictly enforced and regulated. This heavy emphasis on safety by management and working personnel has produced quite a remarkable safety performance. Few critical accidents have been cited in the manual production of small caliber ammunition.

With the growing technological developments in weaponry, there also developed new problems to be overcome. Weapons were being produced which far excelled their predecessors in fire power. Pre-World War II weapons typically were capable of firing seven to ten rounds of ammunition per minute. With the development of highly sophisticated automatic weapons fire power was increased to six to eight hundred rounds per minute. The new electric firing mechanisms, developed within the past five years, have allowed firing rates to climb to an unprecedented 6,000 rounds per minute.

Understandably, pressure was exerted to increase production rates. (The manual methods of ammunition production were capable of rates of only 70 to 80 rounds per minute.) The military became acutely aware of this discrepancy between firing rates and production rates during the Southeast Asian Conflict. Reserve supplies of ammunition were depleted at an alarming rate. Production facilities were operated on a 24 hour, 7 day per week schedule.

In an attempt to remedy this problem, the military conducted an Army Ammunition Production Base Restructure Study. This study disclosed the availability of automated production techniques being utilized in the pharmaceutical industry for the production of medicines. It was found that the rotary turret concept using captive orientation was being utilized. Concept designs substituting small caliber ammunition for pills were soon developed. The first stage in development of high-speed production facilities was concentrated in the very small caliber ammunitions, eg. 5.56mm and 7.62mm. Production equipment has been designed, manufactured, and is currently being used in this area. The second stage in development of the modernization program was to be in the 20mm and 30mm range. It is with this area that this report will be concerned.

The automated processing and production of small caliber ammunition has already been accomplished for the 5.56mm round. Development of the equipment to handle 20mm and 30mm ammunition will logically utilize much of the information and technological advances achieved in earlier work. This will be true in all areas except where major differences exists between the different sizes of ammunition, specifically in the charging of 20mm and 30mm projectiles with a highly explosive chemical blend. The hazards associated with this chemical blend and the handling of this mixture is the subject of this report.

Problem Statement

The problem investigated in this report involves the automating of the handling of High Explosives from the storage site to the production facility. Basic concepts for performing this task will be developed and presented. A hazard analysis will be performed to identi'y and recommend ways to eliminate or control where possible all safety hazards associated with the proposed system.

The problems associated with the handling of this material have resulted as a natural consequence of automating the ammunition production process. Understandably, it is undesirable to limit the productiveness of an automated manufacturing facility by the slow and cumbersome manual handling techniques currently being used. Also, the sizeable increases anticipated in the production rates necessitates increased hazards associated with large accumulations of raw materials. This situation must be either eliminated or designs be made to minimize exposure to this hazard.

Method of Approach

Approaches to solve this increased hazard can basically take two forms. First, the hazard can be limited by reducing personnel and equipment exposure to the hazard. This can be accomplished to a limited degree by proper application of barricades or shielding. The second approach would invlove the reduction of the hazard by limiting and controlling the accumulation of large amounts of explosives at any one point.

It is this second alternative approach that has been investigated in this report. Proper design of a handling system can significantly reduce the number of people exposed to the hazard and also limit the severity of the hazard by providing a continuous flow of materials, thus reducing the large accumulations currently anticipated.

The next chapter will explain details of the Small Caliber Ammunition Modernization Program (SCAMP) and a process description of proposed mechanized equipment.

Chapter III is a survey and explanation of material handling in general terms. Objectives and theories will be presented with applications being oriented toward the handling of high explosive materials.

With an understanding of the processes involved, along with general theories of material handling, a set of system requirements will be developed in Chapter IV.

Chapter V contains a hazard analysis of preferred handling systems and points out problem areas to be eliminated or minimized.

Chapter VI will include recommendations and conclusions based on analysis of handling systems.

CHAPTER II

SMALL CALIBER AMMUNITION MODERNIZATION PROGRAM - MODULE B

The material handling system analyzed in this report is a subsystem of the High Explosive Incendiary Charging Submodule. The High Explosive Incendiary Charging Submodule is likewise a subsystem or constituent part of the SCAMP - Module B production line. To fully comprehend the material handling system which will service the production module, one must fully understand the environment in which it will function. For this reason a description of SCAMP, its origin, and the goals established by the project office will be presented. Also a brief process description of the Module B and of the High Explosive Incendiary Submodule will be described.

SCAMP

The military's response to critical differences between the demand and supply of small caliber ammunition was in the establishment of the Small Caliber Ammunition Modernization Program (SCAMP). The purpose of SCAMP was to provide concentrated efforts in seeking out and developing viable solutions to production problems concerning small caliber ammunition.

Initial efforts of the SCAMP project were concentrated in the small caliber sizes, understandably, since they are smaller and less complicated to produce and require fewer operations in production. This entire area of concentrated efforts was grouped under the heading of Module A. Likewise, Module B is concerned with the modernization of larger caliber ammunition production, specifically 20mm and 30mm and caliber .50 rounds.

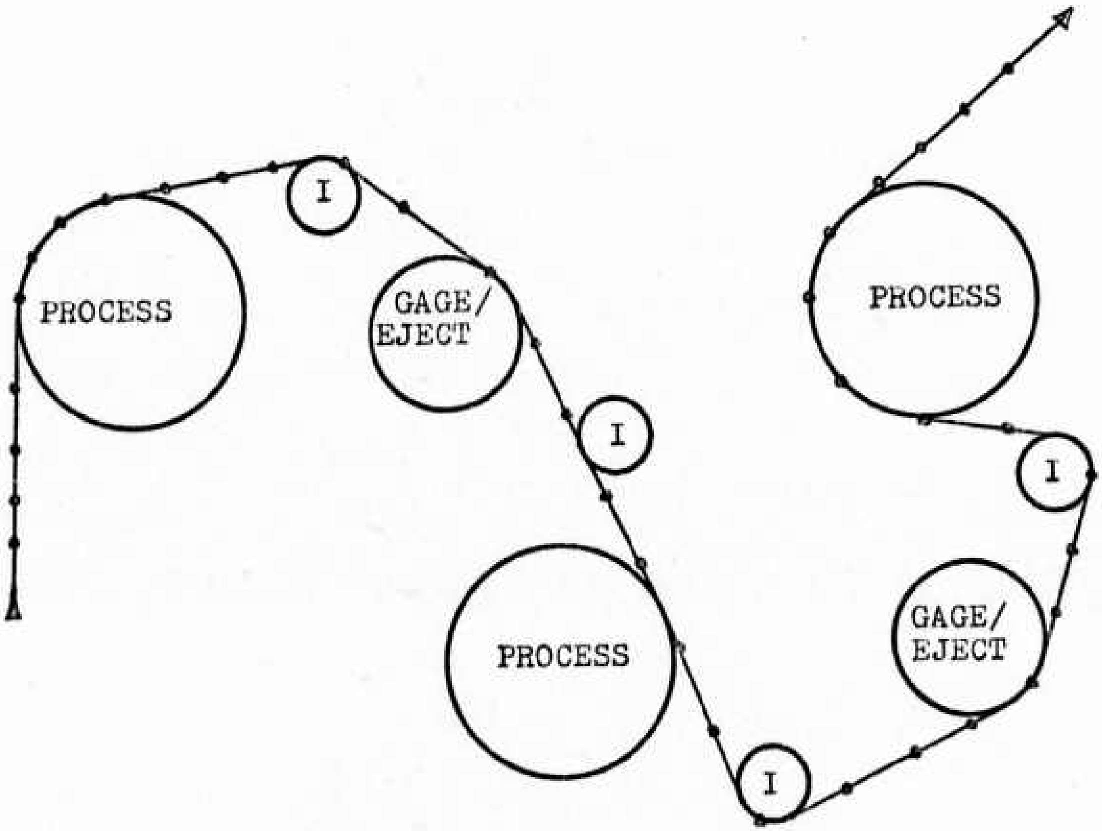
Under the guidance and supervision of program administrators, plans were made to increase the production of small caliber ammunition from 80 pieces per minute to 600 pieces per minute. It became obvious that current manual batch processing techniques could not be used.

Consequently, a new concept in ammunition production was introduced. It was decided to employ the rotary turret concept. (See Figure 2-1). Basically, this concept calls for captive processing of each round by orienting and holding it in place throughout processing.

This is accomplished by placing each round in a continuous link-type belt and moving the belt successively by each processing station. After the round has passed through each processing station a finished round is released to be packaged.

The rotary concept has the advantage of being easily automated. This eliminates the necessity of having operators exposed to the numerous hazards of production. Also, this technique allows for greater efficiency and speed since handling is minimized. Each round remains in a captive position until completion of the processing.

The major disadvantage of such a system is the difficulty



I - IDLER TURRET

FIGURE 2-1 TYPICAL ROTARY PROCESSING STATION of line stoppage due to mechanical failure or other problems. A system such as this would require every station to be functioning properly to allow for continuous operation. It is difficult to conceive any large number of machines functioning properly for an extended period of time due to the limited reliability of any mechanical process. This disadvantage has been overcome somewhat by the introduction of buffers in the assembly lines between each pair of work stations. These buffers allow for temporary differences between station production rates. As long as the accumulators immediately preceding a work station contain work pieces the station can remain in operation regardless of the problems being encountered elsewhere in the line.

Other disadvantages of automation are the expense and limited flexibility of such systems. Sufficient advance planning and forseeability help to minimize problems of flexibility. The tremendous cost of automating this production system can be offset by a significant increase in output with a reduction in manual operations.

Modahl (23.) indicates a projected cost for a typical 20mm round to be approximately $.81, based on a ten year write off and production rates of 19.4 million rounds per month. The current cost of producing a 20mm High Explosive Incendiary round is $1.42, according to the Army Ammunition Production Base Restructure Study conducted in November, 1973. This reduction in cost per round produced can be used to justify automation of current systems.

Module B

Each of the two modules, Module A and B of SCAMP, have been divided into subunits or submodules. In defining these submodules, an attempt was made to equalize the amount of work done by each. Each of these submodules had been vigorously investigated and analyzed as a unit. Contracts have been let on various submodules, treating each as a seperate entity to be designed, developed, and manufactured to fit with each of the other submodules as appropriate. (Refer to Figure 2-1).

To develop a better understanding of Module B and in order to clarify the ammunition production process, each submodule will be presented with a description of the process accomplished by each.

a) Case Manufacture - The purpose of this submodule is to produce the shell casing for each round. This consists of inputing a sheet of steel stock, stamping out the cups, annealing, drawing, trimming, sizing, plating and inspecting the round.

b) Primer Manufacture - This submodule manufactures percussion and electric primers. This operation requires 100% fail safe inspection.

c) Primer Insert - This submodule provides for the positioning and insertions of finished primers into shell casings.

d) Load and Assemble - This submodule receives primed cases, projectiles and propellant. Propellant is dispensed in the cases and then this projectile is placed in the round, thereby resulting in a completed round ready to be packed.

e) Tracer Charging - This submodule provides for the dispensing and consolidation of tracer material into the projectile body after which the projectile is moved to the High Explosive/ High Explosive Incendiary (HE/HEI) charging submodule.

f) HE/HEI Charging - This submodule with which this report is primarily concerned, provides for the automatic dispersing and consolidating of HE chemical blend or pellets into projectiles.

g) Detonator Charge and Assembly - This submodule produces charged fuse detonators which then are assembled into the fuse.

h) Booster Charge and Assembly - This submodule produces charged booster holders that are later assembled in the fuse.

i) Fuse Assembly - This submodule assembles charged rotors and booster holders with the fuse assembly. These assembled fuses are then moved to the fuse-to-projectile assembly submodule.

j) Fuse-to-Projectile Assembly - This submodule receives the fuses and the projectiles. Thread sealant is applied to the projectile body and then the two are assembled.

k) Packaging - This submodule accepts assembled cartridges, links and packing containers. These materials are assembled as required and then the loaded box of linked cartridges moves to the storage area.

l) Ballistic Testing - This submodule provides for the acceptance testing of cartridges. All testing is done automatically with results being sent directly to the Process Quality Control System (PQCS)

m) PQCS - This submodule monitors the entire process by continuously analyzing inspection data received from each of the submodules.

The automated equipment being designed and fabricated for SCAMP module B will have the flexibility to provide for current and future production needs for 20mm, 30mm and .50 caliber ammunition. See Table 2-1 for a list of current production needs.

The type of cartridge being produced determines the process to be utilized in production of that cartridge. See Table 2-2 for a listing of processes used by different types of rounds. In addition, only a predetermined percentage of rounds require tracer charging.

HE/HEI Charging Submodule

The bulk of this report is concerned with the material handling of the chemicals used for High Explosive Incendiary and High Explosive charging of ammunition. For this reason a detailed description of this submodule is in order.

TABLE 2-1

LIST OF CURRENT PRODUCTION REQUIREMENTS

Caliber .50	20 mm	30 mm
Ball M533	HEIT-XM 242	HEDP XM553
Tracer M17	HEIT-SD M246	XM639
	HEI M56A3	
	HEI M56A4	
	TP M55A2	
	TPI M220	

ANTICIPATED FUTURE REQUIREMENTS

20 mm	25 mm	27.5 mm
HEIT M599E1	HEIT- (BUSHMASTER)	HEIT- (BUSHMASTER)
APIT M601E2	APT-	APT-

30 mm
HEIT- (GAU-8)
APT -

TABLE 2-2

SUBMODULES THROUGH WHICH DIFFERENT TYPES OF ROUNDS MUST PASS

20mm/30mm	Caliber .50
Chemical Blend	Chemical Blend
Tracer Charge	Tracer Charge
Bullet Manufacture	Bullet Manufacture
Case Manufacture	Case Manufacture
Primer Manufacture	Primer Manufacture
Primer Insert	Primer Insert
Load and Assemble	Load and Assemble
Packaging	Packaging
Ballistic Test	Ballistic Test
Booster Charge	Process Quality Control
Detonation Charge	
Fuze Manufacture	
Fuze to Projectile Assembly	
Flash Tube Charge	
Process Quality Control	

Figure 2-2 indicates the individual turrets in a conceptualized process layout for the charging submodule. The inputs to this submodule include a projectile which has been tracer charged and a granular mix or pellet composition which will be placed in the projectile. Each projectile will be held in a captive position which provides for reduced handling and correct orientation. Each projectile passes successively by four hoppers containing a highly explosive mixture. The mix is metered out and allowed to enter the projectile at each station. After each hopper there is a hydraulic press which pushes the mixture down into the projectile. This is called consolidation and requires approximately 25,000 psi. pressure applied to the hydraulic pistons.

The depth of the charge is then milled to correct height. The threads are cleaned and the projectile is inspected and gauged. Provisions are made for rejecting rounds which are cracked, chipped, nicked or dented. After passing this inspection the projectile is carried to the next submodule. A prototype of this submodule has been designed and is nearing completion. Table 2-3 outlines old methods versus new methods of charging.

This automated procedure can be only as effective as the system which delivers the raw materials to it. As a result of increased manufacturing capabilities and higher production rates increased hazards associated with the necessity of accumulating larger amounts of explosives at each work station have evolved. A portion of this hazard can be eliminated by the

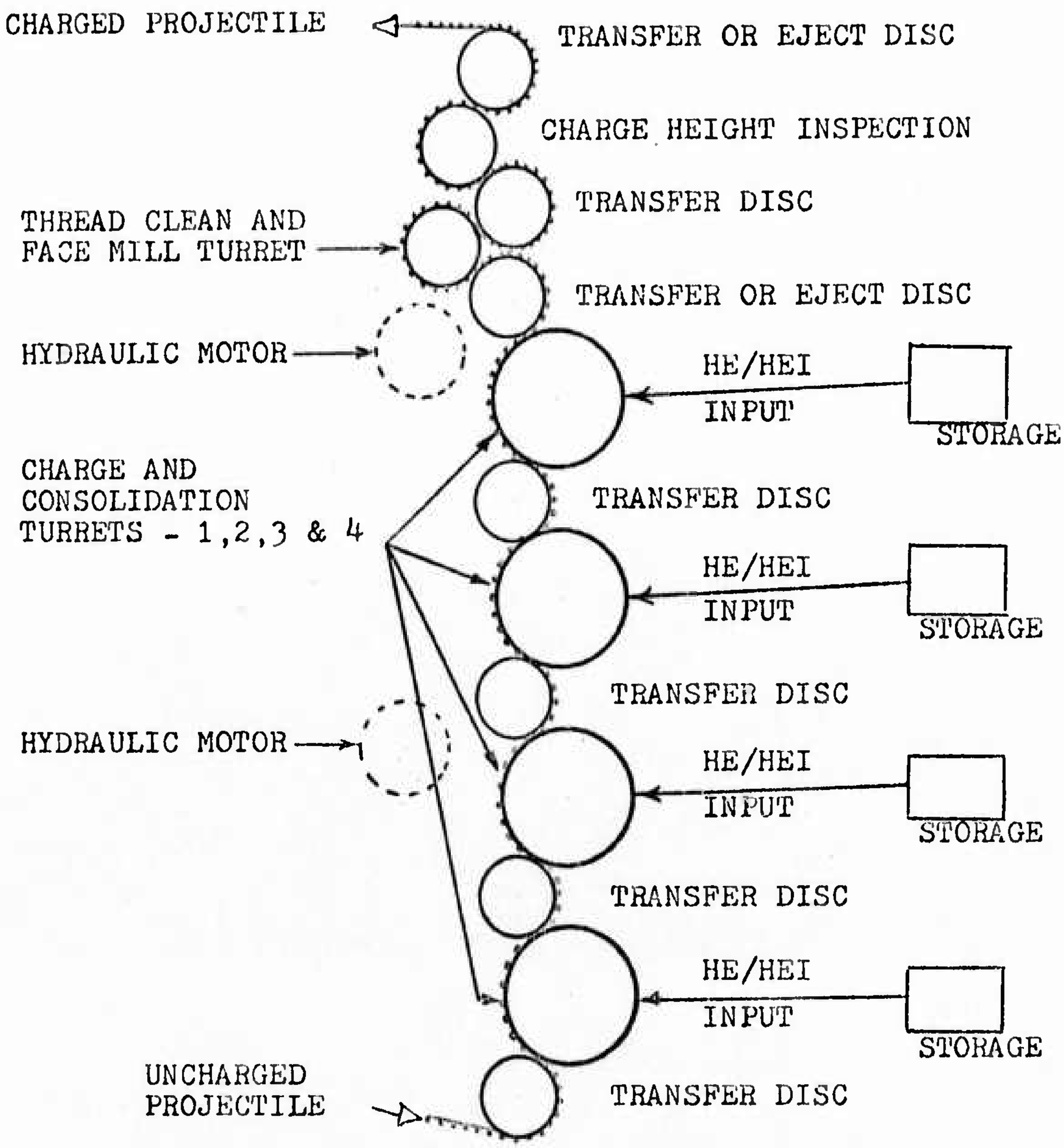


FIGURE 2-2 HE/HEI CHARGING SUBMODULE - TURRET LAYOUT

TABLE 2-3

OLD METHOD VS NEW METHOD

PRESENT PROCESS

1. Insert projectile in charging die
2. Handfeed one $37\frac{1}{2}$ grain LCA #1 pellet
3. Compress to 25,000 psi, minimum
4. Handfeed one $37\frac{1}{2}$ grain LCA #1 pellet*
5. Compress to 25,000 psi, minimum
6. Handfeed one 34 grain LCA #1 pellet
7. Compress to 25,000 psi, minimum
8. Mill to .379 ± .025 depth of charge and vacuum clean
9. Remove projectile from die, inspect for cracks, splits, dents, nicks, burrs, explosive in threads and expanded bodies

* Weight may vary to meet height of charge requirement.

HIGH SPEED PROCESS

1. Orient and feed projectile into charging die
2. Feed loose LCA #1 or WC-870 if required. Consolidate to 25,000 psi if required
3. Feed loose LCA #1 - adjust charge height, consolidate to 25,000 psi
4. Feed loose LCA #1 - adjust charge height, consolidate to 25,000 psi
5. Feed loose LCA #1 - adjust charge height, consolidate to 25,000 psi
6. Mill depth of charge, clean threads and vacuum clean
7. Gauge depth of charge, gauge for expanded bodies
8. Inspect for cracks, splits, dents, nicks, burrs, explosive in threads, etc.

design of an effective, responsive and efficient materials handling system.

In the next chapter, material handling concepts are presented to allow for the logical systematic development of a set of criteria to be used in the design of safe, automated handling systems for High Explosive Incendiary and High Explosive mix.

CHAPTER III

MATERIAL HANDLING

Since the problem to be analyzed in this report is a special case of a materials handling problem there exists a need for an understanding of certain aspects of the science of material handling. Even though the problems encountered in this area are not as well defined and solutions are not as clear cut as in some of the other disciplines, it is to the reader's advantage to understand some of the basic principles, theories, objectives and analysis techniques that have been used successfully in the past.

Background

Man has been concerned with problems associated with materials and the handling of those materials since the beginning of time. Any operation, regardless of its nature, involves some kind of movement of materials. The operation might involve positioning, moving, placing, orienting, or any other form of movement. The mere action of holding an item in position during an operation can be classified as materials handling. The concept is so basic and the need for handling is so universal that it is astounding to discover how little had been accomplished in the area of material handling prior to World War II. It was not until this time that material handling was recognized as being an area deserving careful attention and analysis. It was discovered that many improvements could be made by merely using ingenuity and logic in the handling field.

Material handling is a very difficult concept to formally define. This is due primarily to the fact that basic concepts are usually self explanatory. Basically, materials handling is the movement of materials. The Materials Handling Institute describes material handling in the terms of motion, time, quantity, and space as follows:

> First, Material Handling is MOTION. Parts, materials and finished products must be moved from location to location. Material Handling is concerned with moving them in the most efficient manner.
>
> Second, Material Handling is TIME. Each step in any manufacturing process requires that its supplies are on hand the moment it needs them. Material Handling must assure that no production process or customer need will be hampered by having materials arrive on location too late or too early.
>
> Third, Material Handling is QUANTITY. Rate of demand varies between steps in the manufacturing process. Material Handling has the responsibility of being sure that each location continually receives the correct quantity of parts-pounds-gallons.

Fourth, Material Handling is SPACE. Storage space, both active and dormant, is a major consideration in any building, as space costs money. Space requirements are greatly influenced by the Material Handling flow patterns.

Put these four elements together and you have the basics of Material Handling. It should be noted that these elements are not treated independently. They must be integrated and their composite performance determines the quality of the Material Handling system. (1.)

In any plant or industrial operation a large percentage of the cost involved in the production of an item will be the cost of handling that item. For a pound of material produced many, many pounds of material are moved. It has been estimated that one out of ten in the work force are material handlers. It had been said that for every ton of material produced, fifty tons of material was moved. (3.)

Under normal circumstances the total activity of a manufacturing facility can be described using three basic functions: performing, handling, and control. (Refer to Figure 3-1) For many years management's emphasis has been on performing rather than on moving. Basically, materials handling encompasses two functions: moving and storing.

Objectives of Material Handling

The primary objective of the science of handling is to design systems that deliver material to a desired point

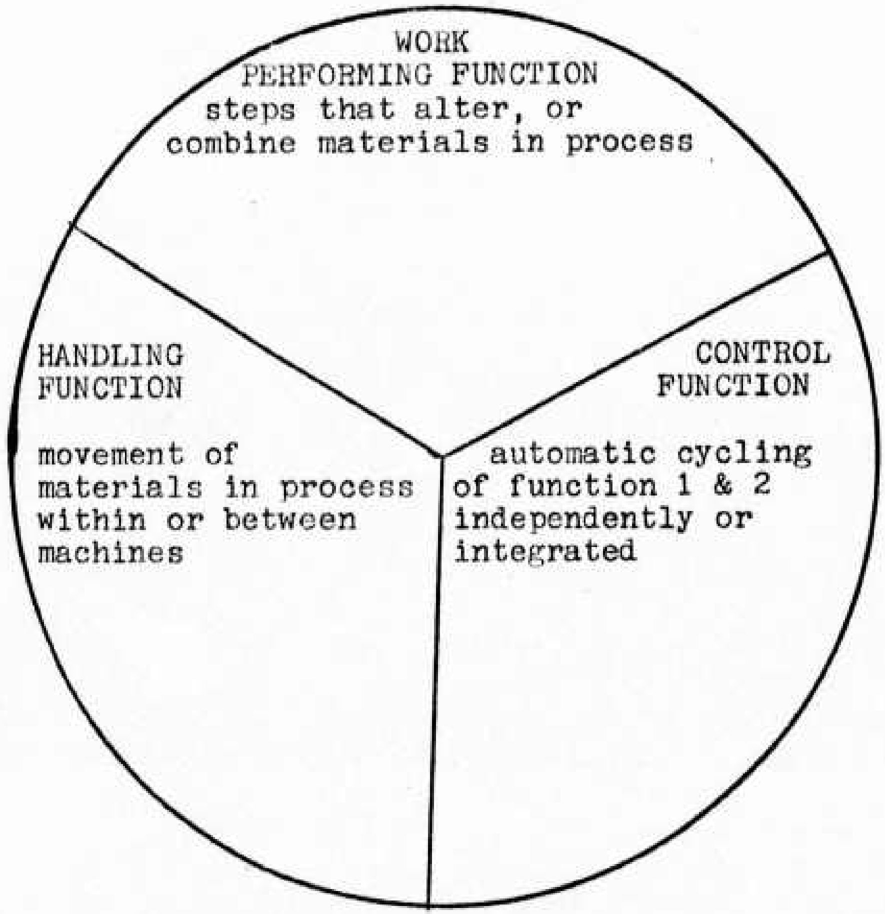


FIGURE 3-1 THREE BASIC FUNCTIONS OF AN ENTERPRISE
(Adapted from Apple (3))

effectively, efficiently, and economically.

Cost reduction involves either reducing the amount of handling necessary or improving the handling system so that overall production costs are reduced. This means that the cost of material handling can actually increase and be totally justified by an increase in production output.

Apple (1) lists several ways in which cost reductions are realized through improved handling:

1. Reducing material handling labor.
2. Reducing the material handling work done by direct labor. High-skill and high-cost labor should not be assigned low-skill, low-cost work.
3. Reducing indirect labor associated with material handling activities, such as shipping and receiving personnel, production control personnel, tool room and storage personnel, inspectors, quality control, repair personnel, etc.
4. Reducing waste and damaged materials through more careful handling.
5. Reducing paper work and associated clerical help through handling systems that minimize control requirements.
6. Reducing the amount of material in the system by faster through-put and less in-process storage.
7. Reducing the amount of subsidiary materials such as packaging materials and other protective

devices such as trays, racks and special containers. This in turn reduces the amount of inspection work.

The second objective of a material handling system is to provide an increase in production capacity. This is accomplished by better space utilization, improvement of plant layout, faster movement, and better utilization.

The third important objective of a material handling system is to improve the conditions under which the employees must function. This includes making jobs easier, safer, and making the work lighter.

Material Handling and Plant Layout

A materials handling problem cannot be attacked as an isolated area seperate and independent of the layout of the facility in which it must operate. Plant layout and materials handling systems go hand in hand; one enhances the other. This relationship is due to the set of constraints imposed by the physical facility in which the production system is to be housed. Planning an efficient material handling system cannot be accomplished independently of the plant layout; the layout and the handling system must be planned together.

Techniques for Analysis

There are practically as many techniques of analyzing a materials handling problem as there are analysts to investigate the problem. Each situation is different. Facilities are different, materials to be moved are different; even the scope and depth of the analysis differ. Each analyst must provide a degree of ingenuity in any handling problem to tailor its solution to fit in his system.

Nevertheless, certain important determinations must be made before a viable solution can be approached. First, the analyst must determine the scope of the problem he is attacking. The scope will depend on many factors, including type of company, type of material handled, economic value of the product, relative importance of material handling to the company, etc. Apple (3) has indicated that in a chronological sense, material handling activity in a company will usually fit one of the three following stages of development: 1) conventional, 2) contemporary, or 3) progressive.

The conventional interpretation of materials handling places primary emphasis on the movement of materials from one location to another, usually within the plant. The analyst is concerned with individual, isolated, independent material handling situations. This approach can best be described as "beating out brush fires".

The contemporary point of view is concerned with focusing attention on the overall flow of materials in the enterprise. The analyst is concerned with interrelationships between all handling problems and with the idea of establishing a general overall material handling plan.

Using the progressive approach to material handling, the analyst visualizes the material handling problems, the physical distribution activities and all related functions as one, all-encompassing system. This point of view is a much broader consideration. It is in this realm that the greatest contributions can be made for the organization.

Too often the analyst begins his analysis with an attempt to answer the question, "How can the material be moved from point A to point B?" This question should be among the last answered if the problem has been properly analyzed. The analyst's primary concern should be :

1) What material is to be moved and why?
2) Where is the material to be moved and why?
3) When is the material to be moved and why?
4) What is the volume of the material to be moved? (6)

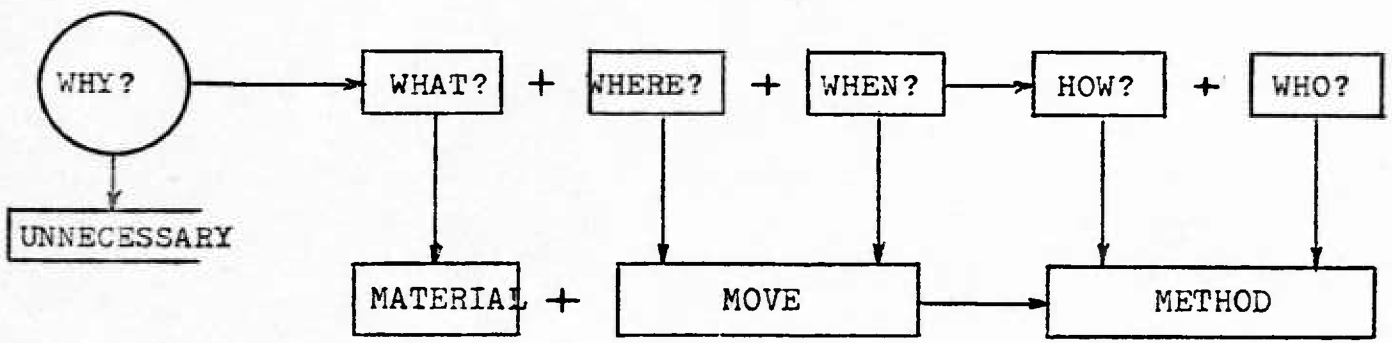
When these questions are answered then the methods to be used will be simplified. This concept can be visualized in Figure 3-2.

Every material handling problem should be analyzed in terms of the three major phases: material, move, and method. Under the material phase one should be concerned with type, characteristics and quantity. The move involves the source and destination, logistics, characteristics, and type. The method covers the handling unit, the equipment, the manpower and the physical restrictions.

Procedure

Like any problem to be analyzed from a logical, systematic approach, the problem must first be defined.

One must identify the problem, determine the scope,



FACTORS
1. Type
2. Characteristics
3. Quantity

FACTORS
4. Source destination
5. Logistics
6. Characteristics
7. Type

FACTORS
8. Unit handled
9. Equipment
10. Manpower
11. Physical restrictions

FIGURE 3-2 THE HOW-WHEN-WHY EQUATION
(Adapted from Apple (3))

establish objectives and carefully define the problem. Next, the problem must be investigated. This involves determining what data to collect, collecting it, and then analyzing it. Finally a solution is determined and then it is installed after adequate testing and justification.

This procedure is not new by any means, but the use of this technique in analyzing material handling problems is a relatively fresh approach. Until recently anlaysts were more concerned with "solving" rather than "analyzing" the problem. This approach has provided many worthwhile solutions but has usually resulted in suboptimal, rather short-range solutions.

In the next chapter the ideas, procedures and principals discussed above will be applied in analysis of a material handling problem.

CHAPTER IV

MATERIAL HANDLING OF HIGH EXPLOSIVE INCENDIARY

A framework of definitions and basic principles of general materials handling theory have been described and developed. It is now time to analyze the problem of handling High Explosives and High Explosive Incendiary. The material handling problem addressed in this report is only a portion of the total material handling problem encountered with the automated production of small caliber ammunition. In fact, the total concept of automated production is little more than an innovative technique of handling materials. From the description of the production process presented earlier, it can be readily seen that approximately 80% of the production line process involves handling of materials exclusively.

The automated handling of high explosives encompasses total material handling process from manufacturing of the blend until the material has been loaded into the round of ammunition. A comprehensive study should be made of the problem encompassing the total handling of this sensitive material. This paper will treat only the portion of the problem involving the movement of the material from the storage magazine to the charging submodule that will load the projectile.

Characteristics of the Material

To properly begin an analysis of any material handling problem it is first necessary to completely understand the characteristics of the material to be moved. In this problem High Explosive and High Explosive Incendiary will constitute the material to be moved. HE/HEI is a chemical blend of a metal alloy, usually magnesium and aluminum and an oxidizer, such as barium nitrate. See Table 4-1 for a list of commonly used incendiaries. The purpose of placing incendiary in a projectile is to provide an effective weapon to be used primarily against aircraft and fuel storage dumps. The major function of the incendiary is to provide a large amount of heat over a few milliseconds that will effectively ignite a gasoline tank. See Figure 4-1 for a diagram of a typical 20mm HEI round. The difference between HE and HEI is in the burn duration time. HE has a shorter burn time. High Explosives consist of RDX, HMX, a composition, or possibly tetryl. HEI is a mixture of an incendiary and a high explosive.

This chemical mixture is handled in two basic modes: 1) granular or powder and 2) consolidated or pelletized. The materials are received and handled in bulk quantities. In some cases the bulk material is consolidated into pellets at the installation and in others the pellets are procured from the supplier. The material is also used in a granular, powder form.

The exact form of the material to be procured and used in

TABLE 4-1

LIST OF COMMONLY USED INCENDIARIES

IM-11

50% magnesium-Aluminum Alloy (50/50)

50% Barium Nitrate

IM-21A

48% Magnesium-Aluminum Alloy (50/50)

48% Barium Nitrate

3% Calcium Resinate

1% Asphaltum

IM-23

50% Magresium-Aluminum Alloy (50/50)

50% Potassium Perchlorate

IM-28

50% Magnesium-Aluminum Alloy (50/50)

40% Barium Nitrate

10% Potassium Perchlorate

IM-68

50% Magnesium-Aluminum Alloy (50/50)

25% Ammonium Nitrate

24% Barium Nitrate

1% Zinc Stearate

IM-69

50% Magnesium-Aluminum Alloy (50/50)

40% Barium Nitrate

10% Iron Oxide ($Fe_2\ O_3$)

TABLE 4-1 (CONTINUED)

IM-112
45% Magnesium-Aluminum Alloy (50/50)
5% Tungsten Powder
50% Barium Nitrate

IM-136
49% Magnesium-Aluminum Alloy (50/50)
49% Potassium Perchlorate
2% Calcium Resinate

IM-139
10% Magnesium-Aluminum Alloy (50/50)
40% Red Phosphorus
47% Barium Nitrate
3% Aluminum Stearate

IM-142
46% Magnesium-Aluminum Alloy (50/50)
48% Barium Nitrate
5% Asphaltum
1% Graphite

IM-241
50% Zirconium (60/80) (lot 6)
25% Magnesium-Aluminum Alloy
25% Potassium Perchlorate (-250)

IM-385
49% Magnesium-Aluminum Alloy (50/50)
49% Ammonium Perchlorate
2% Calcium Resinate

TABLE 4-1 (CONTINUED)

MOX-2B (High Explosive Incendiary Fillers)

52% Aluminum Powder

35% Ammonium Perchlorate

6% RDX/Wax (97/3)

4% TNT (Coated on the Ammonium Perchlorate)

2% Calcium Stearate

1% Graphite

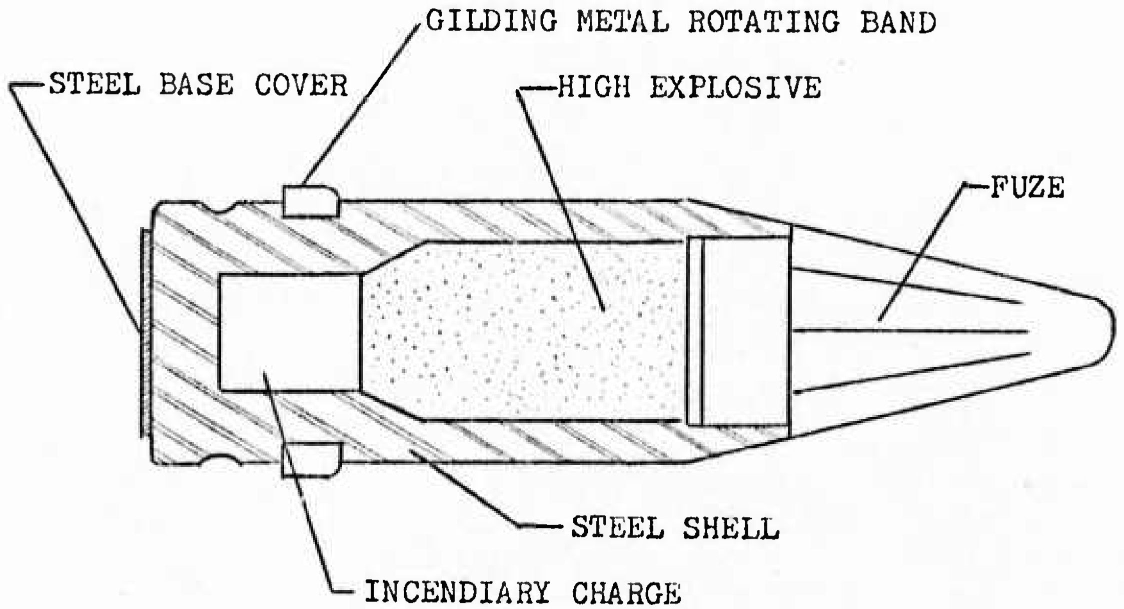


FIGURE 4-1 TYPICAL 20mm HEI ROUND

the charging submodule is not as critical as it may seem. The system can be designed to permit the handling of both forms of the material. There are certain advantages and disadvantages associated with each form, but from an engineering viewpoint it seems more advantageous to use the mixture in the loose form. This would eliminate the added expense of pelletizing the explosive. There would be no problem with the pellets chipping, which at times makes it difficult to control the quantity of explosive placed in the round. With loose material there would be a problem with explosive dust, but there would also be dust problems with pellets due to the chipping and cracking. The pellets also require methods to properly orient and align them in order to allow entry into the round. Because different rounds require different quantities of explosives, several different sizes of pellets might be required.

For reasons listed above, it appears to be advantageous to use explosives in the powder form. Consequently, all system concepts recommended in this report will be based on the assumption that the powder form of material will be utilized.

High Explosives present a set of problems not ordinarily encountered with what is considered typical bulk materials in the material handling discipline. This type of material can detonate and virtually destroy the facility in which it is being used. Besides facilities damage, there is a likelihood of harming personnel in the event of a mishap. For this reason it is desirable to eliminate, where possible, the movement of this type of material by human operators.

Many limitations and restrictions can be determined from the guidelines provided by AMCR 385-100, Safety Manual, concerning the handling, processing, and storage of hazardous materials. A hazardous material is defined as any compound, mixture, element, or assemblage of material which, because of its inherent characteristics, is dangerous to manufacture, process, store or handle. HE and HEI are explosives. The term "explosive" includes any chemical compound or mechanical mixture which, when subject to heat, impact, friction, detonation, or other suitable initiation, undergoes a very rapid chemical change with the evolution of large volumes of highly heated gases which exert pressures in the surrounding medium. The AMCR 385-100 provides a breakdown or categorization of chemicals and explosives by their severity of damage in the event of explosion and their sensitivity to ignition. Several classes of explosives are present in the SCAMP module at all times. Class 2 is defined as being propellants and single-base, single perforated rifle propellent. Class 7 explosive will detonate high order or within a one second period. They are considered to present the greatest degree of hazard and consequently demand the highest degree of protection and concern.

HE/HEI is a Class 7 explosive and all safety regulations governing its use and storage must be adhered to. HE/HEI is sensitive to heat, flame, static electricity discharges and particularly to friction. Since pyrotechnic compositions contain powdered metals, they may become hazardous when exposed to moisture. Compositions in process and pyrotechnics in storage must be protected from moisture.

Material Requirements

In final form the total SCAMP Module B facility being designed and fabricated will consist of two complete ammunition assembly lines. Thus the delivery system for HE/HEI must provide sufficient capacity to supply material needs for two charging submodules.

Several different types of ammunition will be produced on these lines. The quantity of bulk explosives is dependent on the specific round being produced. Refer to Table 4-2 for quantities required for various rounds of ammunition. From the table one can see that there is a sizeable variation between the quantities of material required for the 20mm round versus the 30mm round. The system being designed will need to be flexible enough to handle this situation.

Mr. Green, of the Small Caliber Ammunition Modernization and Engineering Division, Frankford Arsenal, has recommended supplying approximately 1000 lbs./ hr. of HE/HEI to the submodule with not more than five lbs. or less than three lbs. of material at any one turret at any given time. There will be four turrets being supplied which means a total accumulation of 20 lbs. of material at the charging submodule. This delivery rate suggested by Frankford Arsenal would be adequate for any round except the 30mm which would require 3,444 lbs./hr. Of course, this suggested rate could be used by slowing the production rate of the line. By maintaining a smaller amount of

TABLE 4-2

HE/HEI EXPLOSIVE REQUIREMENTS
FOR TYPICAL ROUNDS

20mm	30mm
M56A3 - 14.143 lbs/min	XM639 - 57.4 lbs/min
XM242 - 12.172 lbs/min	
M246 - 9.857 lbs/min	

explosive at each hopper the barricades required in and around the facility could be reduced significantly.

Since the explosive effect will propagate, it is essential to deliver the material in discrete increments of controlled size. Also, since the magnitude of the hazard presented by the material is directly related to the quantity present, unnecessary buildups must be avoided.

Distances to be Moved

The hazardous nature of the chemical being handled precludes the presence of significant quantities within prescribed distances of production facilities. If the magazines currently in use are to be utilized, the separation distance from inhabited buildings for the maximum allowable stored quantity of Class 7 explosives (100,000 lbs.) is approximately 2,200 ft. From a materials handling viewpoint, this magnitude of seperation presents quite a problem, eg. cost, maintenance, etc. Also, the distance is completely exposed to the environment and encompasses varying types and levels of terrain. Original design requirements specify at least one month's supply of raw material being available. This would require a minimum of 320,000 lbs. of explosive at a consumption rate of 1000 lbs. per hour. This indicates that the delivery or handling system would be required to link several storage magazines together. This implies added distances, interlocking devices, central control and monitoring.

The great distances encountered forces the analyst to consider the possibility of intermediate service storage in the proximity of the production line. This system would not be as desirable as a completely automated system but may be dictated by economic constraints.

In accordance with AMCR 385-100, a service magazine or intermediate storage area can be located at intraline distance from a production area. Intraline distance is dependent on the quantities of explosive placed in the storage facility. If it is assumed that 1000 lbs./hr. of explosive was being consumed by the production facility and that two shifts would operate each day, then one day's supply of HE/HEI would be 16,000 lbs. Intraline distance for this quantity of Class 7 explosive is 245 feet if the storage facility is barricaded. This is a significant reduction from 2,200 feet required for separating 100,000 lbs. capacity magazines from production areas.

Other Considerations

AMCR 385-100 specifies certain activities that can be accomplished within the confines of a conventional storage magazine. Opening boxes of bulk explosives is specifically prohibited. In order to input a material handling system directly at the magazine would require several modifications. The magazine would have to be partitioned off and the operation of opening and dumping explosives into a hopper feed would have to be completely isolated from the bulk of hazardous material. There is a possibility of receiving HE/HEI from the manufacturer unboxed, in granular form by rail and using the rail car as the feed hopper for the automated handling system. This concept will be discussed further.

Material Handling System Criteria

Establishment of a set of system criteria becomes a relatively simple matter once an analysis of the situation and material to be handled has been accomplished. Listed below is a set of criteria which a material handling system must satisfy in order to provide for safe and effective automatic handling of High Explosives.

1) Delivery rate of 1000 lbs. per hour
2) Ease of maintenance; self-lubricating, sealed bearings and motor, etc.
3) High degree of reliability for all components and assemblies.
4) Variable speed mechanism for adjusting delivery rates.
5) Preclude possibility of propagation of explosion
   a) Deliver in increments
   b) System abort mechanism
6) Economical to operate,efficient, quick payback on original investment.
7) Tolerable noise levels, ie.; below 90 db.
8) If containers are utilized:
   a) must be electrically conductive
   b) removable from handling system
   c) provisions made for cleaning and drying
9) Handling system must provide protection from environmental effects;

a) temperature

b) moisture

c) humidity

10) Systems must be electrically well grounded

11) System must be flexible and designed utilizing a modular concept to permit rapid replacement of damaged or malfunctioning sections.

12) Must be situated a specified distance from inhabited occupancy or must be sufficiently barricaded.

13) Must be controlled by the Process Quality Control System computer - monitor and feedback

14) Requires placement of manual override in convenient and accessible locations.

15) Must be safely interlocked and synchronized with production equipment to provide material at proper location when required.

16) Might require intermediate accumulation areas to provide a buffering system for the facility.

17) Must provide a system for pre-heating material to equalize temperature of material with ambient temperature of facility to which it has been delivered. This is a precaution to prevent formation of condensation.

18) All drive mechanisms must be adequately guarded. Pinch points should be eliminated.

19) Input to the handling system must have metering

device:

a) volumetric

b) weight

20) Must incorporate dust collection devices at input and output points.

21) All filling and metering devices at the storage point must be powered pneumatically.

22) All electrical power sources for material handling system must be remotely located.

23) All wiring and switches must comply with National Electrical Codes for explosive dust atmospheres.

24) Since regulations prohibit certain operations inside the magazine, an intermediate storage facility is necessitated.

25) Limited manual material handling capabilities will be maintained.

System Concept

Once the characteristics of the material have been determined and the move requirements have been established, all that remains is to match the equipment capabilities with the given situation and a solution to the handling problem has been made.

Many material handling problems can be solved without the addition of special equipment. In the situation currently being investigated, this is not the case. Special handling equipment is both required and recommended.

Two material handling concepts will now be presented. These concepts resulted from consideration given to system requirements and criteria developed earlier. These concept designs are very general at this time.

In the first concept design bulk material would be received and stored in the magazine areas as is currently done. Dispersion would take place from this area daily on a demand basis.

Any system designed to meet the criteria described earlier must first be capable of developing small unit loads of explosives from boxed or containerized bulk powder. To accomplish this, of course, involves the opening of shipping containers. Since safety regulations prohibit the opening of containers of Class 7 explosives inside a magazine, the first portion of the handling system will require manual operations. This means that the material would be first moved by a forklift to some location remote from the magazine. A slight modification of this concept involves transporting the cartons by conveyor to an intermediate storage point. Once at the remote storage site the containers would be automatically opened and dumped into a bulk holding and dispensing hopper. The material would then be metered into protected containers and moved by overhead power-and-free (see appendix) to the production site. The containers should be constructed of electrically conductive material and located at fixed distances on the power-and-free.

The modified concept would all but eliminate the requirements for trucks and forklifts currently used in the magazine area if roller conveyor is used to transport boxes to intermediate storage locations. Second, there would be a significant reduction in the amount of explosive accumulation at both the intermediate storage location and at the production facility. There would not be a need for manual mechanisms to place the mixture into the hoppers at the charging submodule. The response times would be significantly reduced and the overall quality of HE/HEI delivered to the facility should increase due to the environmentally controlled handling containers.

The second material handling concept involves utilizing specially designed railroad boxcars as the dispensing hoppers for a completely automated delivery system. The opening in the bottom of the car would be controlled using an interlocking metering device which could be attached to the box car by an operator after being properly positioned. The metering device would be linked to the central control computer and would be powered pneumatically.

A facility would have to be constructed or possibly an existing facility could be modified to allow the entry of a complete box car and then provide some kind of environmental sealing. Technologically, this would not present any major problems.

Powder would be dispensed directly into carriers spaced some predetermined distance apart as specified in AMCR 385-100. The carriers would then be picked up by on overhead power-and-free system. From here the powder would be moved directly to the charging facility in containers sealed from the environment.

The total operation would be monitored and controlled by the Program Quality Control System. Containers would be dispatched according to the need at the charging submodule as sensed by the control computer. This type of control system would aid in the prevention of unnecessary buildup of hazardous explosives.

Quantity/Distance constraints would have to be applied to the boxcars and likewise to the metering house. It is suggested that the total quantity of explosive present at the facility be limited to 30,000 pounds or approximately two days supply.

For additional flexibility provisions should be made for the accomodation of large trucks at the metering in the event of some unforseen interruptions in railway service.

The only need for a human operator in this system would be in initiating the process when a boxcar first arrives at the facility. This operator could be eliminated also, if additional aligning and monitoring equipment could be justified economically. In addition, since the material being processed is so sensitive and hazardous, it seems reasonable to provide an operator at all times to monitor the system.

It was in the concern for safety and limiting exposure to hazards that this project was originally undertaken. This chapter has presented an analysis of the handling problem. Two concepts have been presented that the author feels offer a basis for further research and development.

The next chapter is devoted to the analysis of the hazards with which a design engineer should be concerned in the early stages of development of an automated delivery system.

CHAPTER V

SYSTEM SAFETY ANALYSIS

There are many types of analyses available to the system safety engineer to evaluate the safety of a system, subsystem, or individual piece of equipment. Any safety analysis can be placed in one of two main categories; predesign and postdesign. As the word implies, a predesign analysis is used to determine and evaluate hazards that might be present in a system to be designed. Since the system discussed in the previous chapters has not been fabricated or the configuration specified, it is logical to begin with a predesign analysis.

An analysis will take on one of two general forms; quantitative or qualitative. The two kinds of analysis are not entirely independent. A qualitative analysis is a nonmathmatical review of all factors that can affect the safety of a product, system, or person. Conditions and events and their consequences are considered first to determine if they could contribute to an accident and secondly, to determine the method of contribution. Understandably, before a quantitative analysis can be accomplished there must first be a qualitative evaluation made. To this evaluation, probabilities of occurence are added and then one has a quantitative analysis. At this time the greatest contribution to recognizing, minimizing and possibly eliminating hazards associated with the handling system can be made by performing a Preliminary Hazard Analysis.

Preliminary Hazard Analysis (PHA)

A PHA is an analysis which consists of determining safety problems during the early stages of design and development that may cause problems or safety degradation during the operational phase. It is a cursory type of review of any and all perceived safety problems.

The equipment alluded to in the last chapter, although currently in existence, has not been used in the prescribed configuration. The material handling system which these various types of equipment will make up provides the system for this analysis.

The Preliminary Hazard Analysis is an orderly listing of the hazards, the cause of the hazards, the effects of the hazards, hazard categories and corrective or preventive measures. This data will be presented where possible, using a matrix format. When necessary, the narrative format will be used to aid in the description of the hazards.

The Preliminary Hazard Analysis should provide an objective basis from which the subsequent system safety effort, criteria, and requirements for the program will be developed.

Sources of Data

The Preliminary Hazard Analysis is one of the first analyses accomplished on a conceptualized system. Many times the data available will be somewhat incomplete and informal. For this reason, the analysis should be flexible enough to allow for changes and updates as the initial design is modified and changed. In the previous chapter a conceptual design was presented for automatically handling High Explosives and High Explosive Incendiaries.

The system to be analyzed is composed of three basic elements; an input, a move, and an output. The important hazards associated with this handling system are present throughout the total process from the moment the material is metered from the boxcar until it is demanded and dumped into the charging submodule hopper.

Hazard Categories

Each hazard listed in the analysis that follows has had a categoric number associated with it. These numbers are relative degrees of hazard severity as determined subjectively by the author. The Military Standard 882, System Safety Program For Systems and Associated Subsystems and Equipment: Requirements For, defines a hazard level as a qualitative measure of hazards stated in relative terms.

The standard defines hazard levels as : Conditions such that personnel error, environment, design characteristics, procedural deficiencies, or subsystems or component failure or malfunction:

(a) Category I - Negligible:

will not result in personnel injury or system damage

(b) Category II - Marginal:

can be counteracted or controlled without injury to personnel or major system damage

(c) Category III - Critical:

will cause personnel injury or major system damage, or will require immediate corrective action for personnel or system survival

(d) Category IV - Catastrophic:

will cause death or severe injury to personnel, or system loss.

The hazard categories provide the design engineers with a subjective feel for where efforts should be spent in order to minimize risk to the system or to personnel.

A Preliminary Hazard Analysis follows:

PRELIMINARY HAZARD ANALYSIS

System : Automated Material Handling System

HAZARD	CAUSE	EFFECT	CATEGORY	CORRECTIVE OR PREVENTIVE MEASURE
Fire	Combustible material and ignition source. Open flame- employee Sparks- equipment. Heat from friction. Vegetation fire. Spontaneous combustion of trash or oily rags. Ignition of flammable dusts- magnesium & aluminum. Ignition of flammable liquids.	Structural damage. Possible explosion. Equipment damage. Production of toxic gases. Burns of personnel. Contamination of explosive mixture. Heat & reduction of oxygen.	II	Keep work areas clean and clear of debris. Cut vegetation around building and carrier system. Remove combustible dust by proper ventillation or collection devices. Keep machinery well lubricated and provide shut offs in case of heat buildup. Do not allow smoking or other heat sources in area. Provide adequate sprinkler protection and monitoring devices. Perform all maintenance under close supervision (especially welding operations) Provide emergency exits and passageways for employees. Do not allow flammable liquids or gases in area. Obey all wiring codes concerning electrical devices used in combustible dust atmospheres. Provide non-combustible or fire resistive construction. Provide mobile fire extinguishers.

TABLE 5-1

PRELIMINARY HAZARD ANALYSIS

System : Automated Material Handling System

HAZARD	CAUSE	EFFECT	CATEGORY	CORRECTIVE OR PREVENTIVE MEASURE
Explosion	Ignition of sufficient accumulation of explosive form. Ignition of combustible dust. Combustible gases in presence of oxidizer. Heated pressure vessel. Exposed flammable liquids and gases.	Destruction of facilities and equipment. Complete production shut-down. Personnel injury and possible death. Blast overpressures Propagation to other explosives. Fragmentation. Fire and heat.	IV	Isolate explosives from all ignition sources. Barricade personnel to prevent injury. Provide blast pressure relieving structures. Use reinforced concrete dividing walls. Do not allow unnecessary accumulations of explosives. Provide monitors and interlocks to warn of or prevent unwanted accumulations of explosives. Provide escape routes for employees. Plan cleanup procedures. Maintain system backup capabilities. Maintain safe quantity- distance relationships to prevent explosion propagation.

TABLE 5-1

PRELIMINARY HAZARD ANALYSIS

System : Automated Material Handling System

HAZARD	CAUSE	EFFECT	CATEGORY	CORRECTIVE OR PREVENTIVE MEASURE
Electrical	Inadequate insulation. Damaged insulation. Personnel contact with unprotected terminal or switch. Defective device. Burned or overheated conductor. Stray currents from lightning or static electricity.	Electrocution. Uncontrolled reaction and injury. Burn. Explosion of chemicals. Complete system failure.	II	Provide all electrical components in compliance with National Electrical Codes. Provide adequate fusing. Ground and bond all equipment. Provide protection from electrical connections. Isolate explosives from stray currents. Never cut into insulated live wire. Halt current flow before performing maintenance. Provide backup power source or manual methods of moving explosive materials. Isolate all electrical systems from explosives. Provide proper protective clothing and shoes. Maintain proper humidity.

TABLE 5-1

PRELIMINARY HAZARD ANALYSIS

System : Automated Material Handling System

HAZARD	CAUSE	EFFECT	CATEGORY	CORRECTIVE OR PREVENTIVE MEASURE
Motion	Rapid movement of overhead power-and-free. Power transfer of empty containers. Movement of carriers within building. Opening and closing of doors for entering and exiting carriers. Drive mechanisms.	Pinch points which can cause injury to personnel or ignition of explosives. Possibility of being struck by carrier. Hand and foot injury from power transfer. Personnel injury from opening and closing doors.	II	Keep buildup of explosive material to a minimum at any pinch point. Provide adequate guards. Instruct personnel of all moving hazards. Mark off all hazardous areas. Shut down equipment to perform maintenance. Provide warning signals for doors.

TABLE 5-1

PRELIMINARY HAZARD ANALYSIS

System : Automated Material Handling System

HAZARD	CAUSE	EFFECT	CATEGORY	CORRECTIVE OR PREVENTIVE MEASURE
Toxicity	Movement of dust producing explosives. Leakage of containers. Improper ventillation Improper dust control Failure to provide proper personnel protection. Failure of air sampling monitor.	Inability of operator to breathe. Damaging effect on pulmonary system. Possible death of operator. Possible explosion or fire. Skin irritation.	III	Provide adequate ventillation. Provide dust collection devices. Provide monitors to warn of malfunction. Provide emergency breathing apparatus. Isolate operator from movement of explosives. Assure high quality seals on containers. Inspect regularly. Provide wash down area in metering facility. Provide protective clothing for personnel.

TABLE 5-1

PRELIMINARY HAZARD ANALYSIS

System : Automated Material Handling System

HAZARD	CAUSE	EFFECT	CATEGORY	CORRECTIVE OR PREVENTIVE MEASURE
Noise & Vibration	Irregular motion of rotating drive pulley on power-and-free. Loose mountings. Failure of shock absorbing mounts on powered equipment. Missing or misplaced vibration isolators. Reciprocating action of metering device. Rubbing noise due to poor lubrication.	Fatigue and irritability of personnel. Static charge buildup. Unnecessary wear. Hearing damage. Fatigue failure of wire control leads. Fatigue failure of support structures or of overhead line.	II	Provide adequate hearing protection devices with instruction to use them. Provide dampering of vibration sources. Isolate operators and monitoring personnel from equipment. Provide proper preventative maintenance and repair all worn or damaged parts. Inspect for signs of fatigue failures. Inspect wire connections and leads to vibrating equipment. Provide proper grounding and bonding of equipment to prevent static charge buildup.

TABLE 5-1

PRELIMINARY HAZARD ANALYSIS

System : Automated Material Handling System

HAZARD	CAUSE	EFFECT	CATEGORY	CORRECTIVE OR PREVENTIVE MEASURE
Humidity, Contamination, & Condensation	Inadequate protection from environment. Operations performed outside without proper containers. Contamination of explosives from material wearing off containers and handling equipment. Improper location of entrances and exits. Improper sealing of containers. Improper sealing of facilities. Improper preheating of transported explosive. Inadequate cleaning of containers prior to use.	Loss of material due to degredated condition of explosive. Possible explosion caused by chemical reaction of explosive with moisture. Ignition of explosive due to rubbing action or chemical reaction with other contaminants. Poor quality control. Electrical shorting of electrical equipment. Possible static charge buildup.	III	All containers used in this system must be sealed from the environment. Inspect for damaged seals and containers periodically. All metering and dispensing operations should be accomplished in a humidity and temperature controlled bldg. Use high reliability environmental monitors and maintaining devices. Allow for temperature equalization of transported explosive and operating bldg. Provide for screening and filtration to remove loose particle contaminants. Maintain proper humidity level to impede static charge buildup. Provide grounding and bonding.

TABLE 5-1

Discussion

The hazard analysis shows the existence of several types of hazards. Some of these hazards contribute to the existence of other hazards. Some of the hazards are true primary hazards.

From the analysis it can be seen that explosion is the hazard with which most of the design engineer's energy and ingenuity must be directed. Class 7 explosives are present throughout the handling system in varying quantities. This type of explosive is extremely sensitive to heat, friction, or static discharge and can be ignited by the heat of reaction created when it comes in contact with water.

Explosions of very small quantities of Class 7 explosives are not uncommon using the current manual operations for charging projectiles. The true hazard is not the material exploding. The true hazard lies in the explosion of a quantity of material capable of inflicting injury or damaging property.

The new generation equipment being designed will be capable of manufacturing explosive rounds at rates of 600 PPM. This increase in production rates means a necessary increase in quantities of explosives in process. The larger quantities of explosives demand the attention of the design engineer.

Primary contributing factors to this hazardous condition are contamination by moisture and humidity and the inevitable buildup of static charge when the powder is moved or handled. The creation of static charge when material is moved or processed is an inevitable fact of nature. Since the creation of static charge cannot be eliminated, retention level must be controlled. The problems of static electricity and moisture contamination can be handled simultaneously. By controlling the level of humidity and keeping it above 50% greatly inhibits the retention of static charge. Of course, the higher the humidity the less the charge retention but the greater the problem of moisture contamination. A tradeoff is required. Optimal conditions seem to be in a range of 50% to 60% relative humidity. In addition, all equipment and carriers should be adequately grounded to provide for the release of any charge that might accumulate.

The second important consideration should be the limiting of explosives accumulation and strict adherence to quantity-distance relationships to inhibit the propagation of explosion in the event of an incident. The design concept offered in the preceeding chapter provides a solution to the accumulation problem by limiting the amount of explosives carried in each container attached to the overhead power-and-free.

The third consideration should be to limit the number of people exposed to the hazard. This has been achieved by automating the handling where possible and monitoring operations by computer. It has been suggested that interlocks be provided to shut the system down when anything interferes with the movement of the system.

As a last resort in situations where personnel cannot be completely removed from the process they should be adequately protected from the hazard by shields and explosive quantities kept to an absolute minimum.

The next chapter contains recommendations for further analysis conclusions based on the work accomplished in this report.

CHAPTER VI

RECOMMENDATIONS AND CONCLUSIONS

The handling of High Explosive Incendiary and other explosive chemical mixtures presents many problems. Automating the handling and movement of this chemical serves to amplify the problems by the mere fact that larger quantities of material will be processed and moved per unit of time. An increase in the production base necessarily implies creation of problems of explosive accumulation. With increased accumulations comes increased hazard levels and increased risk. The potential damage that would be inflicted in the event of an accident increases rapidly with increases in accumulated explosives. The first rule in explosive safety is to limit this accumulation where possible. Where it is not possible to limit accumulations the next thing to consider is isolation of the hazard from protected areas. With explosives this is accomplished by placing the accumulation a sinificant distance from protected areas or by placement of an adequate barricade between the hazard and the area requiring protection. In some instances both methods of protection are used.

A study has been conducted of the material handling situation; material characteristics and requirements have been determined and environmental conditions have been specified. Several specific material handling systems were looked at along with different techniques for analyzing material handling problems in general. A set of material handling system criteria was developed from a combination of these considerations. Two very general design concepts were then presented for further study.

It is extremely important that basic design problems dealing with safety be brought to the attention of the design engineer in the early stages of design. It is at this time that the maximum benefits can be derived with the minimum capital expenditure. The alternative to this approach is retrofit, generally a very costly and time consuming alternative to be avoided where possible.

As an aid to design engineers, a Preliminary Hazard Analysis was performed of the conceptual material handling systems. An attempt was made to be general in hazard analysis but to be fairly comprehensive. Each of the hazards identified in the analysis was catergorized and recommendations were made concerning methods to eliminate or control the effects of each.

There are many things which must be considered in the analysis of any material handling problem. Analysis techniques used in this report are applicable to almost any handling problem with only slight modifications. This procedure was used to demonstrate and present some of the recently developed techniques for analyzing material handling problems that utilize a systems approach to problem solving.

It is the recommendation of the author that more detailed studies be made to expand the analysis already performed to further identify and eliminate or determine methods of controlling hazards. There is no question that the material handling system serving the automated small arms ammunition production facility will someday be automated. For this reason it is very important to accomplish an adequate amount of analysis to identify problems as early as possible in system development.

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APPENDIX

GLOSSARY

Barricade - An intervening approved barrier, natural or artificial, of such type, size and construction as to limit in a prescribed manner, the effect of an explosion on nearby buildings or exposures.

Cartridge - A tubular case containing the propellant powder and primer of small arms ammunition.

Class 2 - A class of explosives which includes such items as solid propellant composition determined to have a low detonation sensitivity.

Class 7 - A class of explosives which includes such items as bulk high explosives, and high explosive warheads determined to have a high detonation sensitivity.

Explosive - Any chemical compound or mechanical mixture which when subjected to heat, impact, friction, detonation or other suitable initiation, undergoes a very rapid chemical change with the evolution of large volumes of highly heated gases which exert pressures in the surrounding medium.

Hazard - A condition with the potential of causing injury to personnel, damage to equipment or structures, loss of materiel, or lessening of the ability to perform a prescribed function.

HE/HEI - High Explosive/High Explosive Incendiary. A chemical blend of explosives used in the warhead or projectile of a small caliber round.

Incendiary - A chemical blend of a metal alloy, usually magnesium and aluminum and an oxidizer. Produces large amounts of heat for extended periods of time when ignited.

Intraline distance - The distance used to separate buildings or processes accomplished within one operating line.

Inhabited building - A building or structure other than operating buildings, magazines and auxiliary buildings occupied in whole or in part as a habitation for human beings, or where people are accustomed to assemble.

Material Handling - The handling of materials including the movement, positioning and storage of the material.

Magazine - A structure designed or specifically designated for the storage of explosives and ammunition.

Magazine area - A restricted area, specifically designated and set aside from other portions of the establishment for the primary purpose of ammunition and explosives storage.

PHA - Preliminary Hazard Analysis - An analysis consisting of making a study during concept of early development of a product or system to determine the hazards that could be present during operational use.

PPM - Parts Per Minute.

PQCS - Process Quality Control System - A submodule of the SCAMP system which consists of a master computer that continuously analyzes the input data.

Propellant - Explosive compositions used for propelling projectiles.

Quantity Distance - The quantity of explosives material and distance seperation relationships which provide defined types of protection. These relationships are based on levels of risk considered acceptable for the stipulated exposures. These distances have been tabulated and can be found in the AMCR 385-100, Safety Manual, Chapter 17.

Round - An increment of ammunition, a single shot, a cartridge.

SCAMP B - Small Caliber Ammunition Modernization Program, Module B - An Army program designed to modernize the production base currently used to produce small caliber ammunition.

Small caliber ammunition - That class of ammunition that range in size from 5.56mm to 30mm in size.

Submodule - A subsystem of a module. The combination of all the submodules constitutes a module.

Sensitivity - An inverse function of the energy expended in creating a disturbance that is just sufficient to cause initiation.